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## ASSESSMENT OF AIR QUALITY IN TURIN BY PERSONAL MONITORING OF NONSMOKERS FOR RESPIRABLE SUSPENDED PARTICLES AND ENVIRONMENTAL TOBACCO SMOKE

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Exposure to respirable suspended particles (RSP), environmental tobacco smoke (ETS) particles, nicotine, and 3-ethenylpyridine (3-EP) was assessed in Turin for 188 subjects during February and March 1995. Personal monitors were worn over a 24-h period, each subject providing a saliva sample for cotinine analysis both prior to and following the monitoring period. Comprehensive lifestyle questionnaires were also completed before and after the 24-h monitoring period. The study comprised housewives in one group, primarily for assessing exposures in the home, and office workers in a second group to assess exposures in the workplace. A single personal monitor was worn by each participating housewife, while employed subjects wore one monitor at work and a separate monitor at home and elsewhere. Based on median 24-h time-weighted average exposures, the most highly exposed subjects to RSP, ETS particles, nicotine, and 3-EP were office workers living with smokers and employed in locations where smoking was allowed. Annualised exposures for nonsmokers living and working in smoking environments indicate that the home contribution to RSP is between 3 and 4 times that obtained from the workplace. Similarly nicotine and ETS particle contributions from the home are, respectively, 4 and 7 times more than those obtained from the workplace. Subjects living and working with smokers had the highest median saliva cotinine levels of 1.7 ng mL<sup>-1</sup>. Using a cut off level of 25 ng mL<sup>-1</sup>, up to 6.5% of subjects were found to have misreported themselves as nonsmokers. ©1997 Elsevier Science Ltd

### INTRODUCTION

The European Commission has formally adopted a directive on ambient air quality, the framework document for the establishment of outdoor air quality objectives for all the member states. Threshold values will be set for major industrial and vehicular pollutants including SO<sub>2</sub>, NO<sub>2</sub>, and particulates. Strong protective air pollution standards introduced into the United States have demonstrated that this type of strategy can be effective.

The latest figures from the USEPA indicate that the concentrations of most criteria pollutants have fallen steeply over the past 10 years. The overall trend is encouraging but is a generalization since 30% of U.S. citizens live in areas where air quality fails to meet health standards. The same may be said for some member countries of the European Community. These pollutants are considered to have an effect on the indoor environment whether buildings are naturally or

mechanically ventilated. Other pollutants found indoors have their origins defined by sources including heating and cooking facilities, household cleaners, office equipment, furnishings, the building materials, and occupants themselves.

Personal air monitoring in this study was carried out in Turin during February and March 1995. In order to evaluate exposures to environmental tobacco smoke (ETS) particles and respirable suspended particles (RSP), homes and workplaces were classified as smoking or nonsmoking. ETS particles were measured using ultraviolet absorbing particulate matter (UVPM), fluorescing particulate matter (FPM), and solanesol related particulate matter (SolPM). Other recent studies have used a similar methodology (Sterling et al. 1996; Jenkins et al. 1996; Baek et al. 1997).

Turin was the third successive major European city studied by these authors on air quality following investigations in Stockholm (Phillips et al. 1996) and Barcelona (Phillips et al. 1997). Personal monitoring took place over a 24-h period, while volunteers also self-reported activities using diaries and questionnaires. Saliva samples were taken for cotinine analysis before and after the 24-h period.

The main objective of this study was to determine personal exposures of nonsmoking inhabitants in Turin over a 24-h period, and to assess and compare these exposures in the workplace and at home.

## METHODS

### *Recruitment of subjects*

The Mosaic geodemographic classification system, as utilised by marketing companies and used previously by these authors (Phillips et al. 1996), was not available at the time of recruitment in Turin. Instead, a local segmentation system was employed which classified the inhabitants of Turin into "clusters" based upon the same principle as Mosaic. The sample was chosen to be compliant with the following criteria:

- 1) All subjects to be nonsmokers living within 10 km of the city centre of Turin;
- 2) A third in each of the three age groups 20-34, 35-49, and 50-64;
- 3) Equal percentage distribution in geodemographic "clusters" as for the population within 10 km of the city centre; and
- 4) Subjects to be distributed between six "Cells" as indicated in Table 1, Cells 3-6 being targeted at office workers.

The volunteers in this study were recruited using randomly selected telephone numbers from files created in accordance with the above criteria. Initial telephone contact was performed by Teleperformance, a large opinion research bureau resident in Italy, at which point prospective study participants were screened to confirm their eligibility to take part. This screening included questions concerning age, current and previous smoking status, other nicotine product use, and employment status. Suitable volunteers were then given an appointment to attend an information/training session organised at the Hotel Diplomatic in Turin.

The Mosaic classification system for Turin was developed after this study had been completed. A comparison of the sample of the present study with the population of Turin was then possible.

### *The monitoring session*

The personal monitoring methodology was described previously by these authors (Phillips et al. 1996) and consisted briefly of the following:

- 1) Initial visit to the study centre: Subjects were issued personal monitors and diaries/questionnaires for recording exposures and observations over the 24-h collection period. Full instructions regarding use of the monitoring equipment and how to complete the study diaries and questionnaires were provided. Nonworking subjects recruited for participation in Cells 1 and 2 (housewives) were provided with a single personal monitor for use over the collection period (single monitor study). Working subjects recruited for participation in Cells 3 to 6 were provided with two personal monitors for use over the same period (dual monitor study). Subjects were required to provide a saliva sample prior to the monitoring period (pre-sample).
- 2) Final visit to the study centre: Following completion of the 24-h monitoring period, subjects were required to return their personal monitors and associated documentation to the study centre. Subjects also provided a second saliva sample (post-sample) and completed a "last visit" questionnaire.

### *The personal monitor*

The personal monitor was designed to collect particulate and vapour phase components present in the air close to the subject's breathing zone, as described previously (Ogden et al. 1996; Phillips et al. 1996). RSP and ETS particles were collected onto a Fluoropore membrane filter. Nicotine and 3-EP were adsorbed onto XAD-4 resin beads.

Table 1. Planned distribution of study subjects based on their household and workplace smoking status (Turin).

Cell	Study type	Smoking status		Target number
		Household	Workplace	
1	Single monitor	Smoking	-	55
2	Single monitor	Nonsmoking	-	40
3	Dual monitor	Smoking	Smoking	45
4	Dual monitor	Smoking	Nonsmoking	30
5	Dual monitor	Nonsmoking	Smoking	40
6	Dual monitor	Nonsmoking	Nonsmoking	30

Table 2. Limits of quantification for the analytical methods according to collection period (Turin).

Measurement	Collection period		
	24 h	15.59 h *	7.36 h **
Respirable suspended particles (RSP) *	7.67 $\mu\text{g m}^{-3}$	11.8 $\mu\text{g m}^{-3}$	25.0 $\mu\text{g m}^{-3}$
ETS particles estimated by UV (UVP) *	0.50 $\mu\text{g m}^{-3}$	0.77 $\mu\text{g m}^{-3}$	1.64 $\mu\text{g m}^{-3}$
ETS particles estimated by fluorescence (FPM) *	0.12 $\mu\text{g m}^{-3}$	0.18 $\mu\text{g m}^{-3}$	0.38 $\mu\text{g m}^{-3}$
ETS particles estimated by solanesol (SolPM) *	0.28 $\mu\text{g m}^{-3}$	0.44 $\mu\text{g m}^{-3}$	0.93 $\mu\text{g m}^{-3}$
Nicotine **	0.09 $\mu\text{g m}^{-3}$	0.13 $\mu\text{g m}^{-3}$	0.28 $\mu\text{g m}^{-3}$
3-Ethenylpyridine (3-EP) **	0.09 $\mu\text{g m}^{-3}$	0.13 $\mu\text{g m}^{-3}$	0.28 $\mu\text{g m}^{-3}$
Saliva cotinine	1.00 ng mL <sup>-1</sup>	-	-

\* Mean time spent outside the workplace for working subjects in Turin.

\*\* Mean time spent at work for working subjects in Turin.

\* Calculated assuming a flow rate of 1.72 L min<sup>-1</sup> through the Fluoropore filter.\*\* Calculated assuming a flow rate of 0.80 L min<sup>-1</sup> through the XAD-4 tube.

## ANALYTICAL PROCEDURES

All analytical procedures were validated and were fully described previously by these authors (Phillips et al. 1996). In this study, the following analytes were determined:

- 1) RSP—using a gravimetric procedure;
- 2) Saliva cotinine—using a radioimmunoassay procedure (Van Vunakis et al. 1987);
- 3) Nicotine and 3-EP—using a capillary GC procedure (Ogden et al. 1989); and
- 4) Estimation of ETS particles (3 methods)—using high performance liquid chromatography (HPLC) procedures to determine the UVP, FPM, or SolPM of methanolic filter extracts (Ogden et al. 1990). The factors used in this study to convert instrument responses into an equivalent concentration of ETS particles were 47 (SolPM), 45 (FPM), and 8.3 (UVP), as determined by Nelson et al. 1997.

The limits of quantification (LOQ) for these analyses are presented in Table 2.

## SUBJECT SELECTION

Of the 208 subjects initially recruited for the study, 7 were excluded because they failed to collect their samples, 10 subjects were excluded after they admitted to being smokers during their initial visit to the study centre, and 3 subjects were excluded because their saliva cotinine levels were above the selected threshold (25 ng mL<sup>-1</sup>) for nonsmokers.

The age and sex distributions of the remaining 188 subjects who successfully completed the study are presented in Table 3. Figure 1 shows that the sex distribution for employed subjects was close to that planned of 50:50 males and females but slightly over-represented by males compared to the Turin population.

Table 3. Age and sex distribution of the study subjects (Turin).

Cell *	Sex		Age range			Overall total
	Males	Females	20 - 34	35 - 49	50 - 64	
1 (SH)	-	36	17	12	7	36
2 (NSH)	-	47	13	10	24	47
3 (SH, SW)	14	7	14	3	4	21
4 (SH, NSW)	6	3	6	2	1	9
5 (NSH, SW)	27	24	24	24	3	51
6 (NSH, NSW)	13	11	10	11	3	24
Single monitor total	-	83	30	22	31	83
Dual monitor total	60	45	54	40	11	105
Overall total	60	128	84	62	42	188

\* SH: smoking household; NSH: nonsmoking household; SW: smoking workplace; NSW: nonsmoking workplace.



Fig. 1. Comparison of sex distribution of working subjects with the population of Turin.

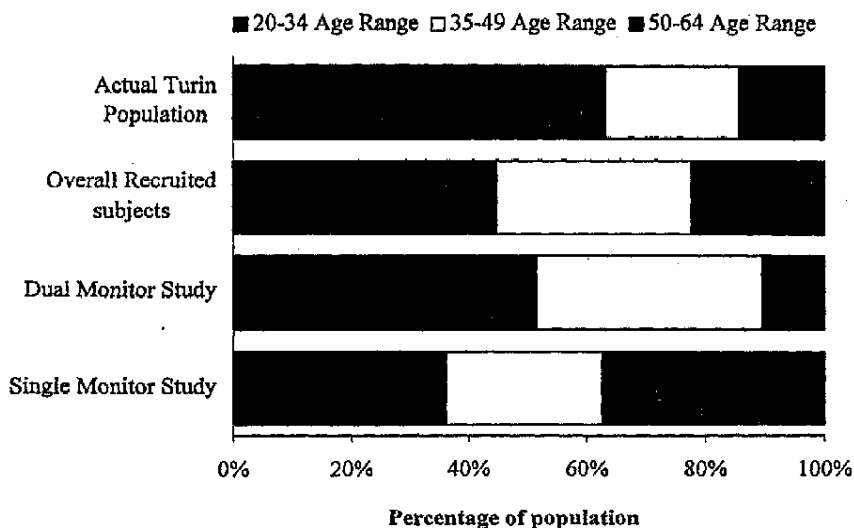
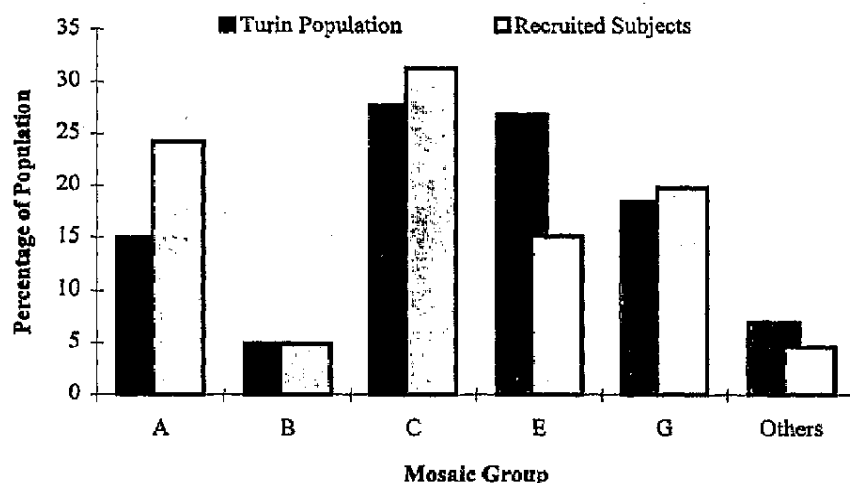


Fig. 2. Comparison of age range distributions for all study subjects with those of the population of Turin.



Mosaic group	Description of constituent types
A	High income professionals/executives in large homes, older age groups
B	Young families, highly educated, high income white collar workers in large homes
C	Small households of average education employed in service sector, upper age group, many pensioners
E	Young families in large households employed by manufacturing and construction industry, poor education, many unemployed
G	Small middle-aged households, blue collar workers employed by manufacturing industries

Fig. 3. Comparison of the geodemographic Mosaic distributions for all recruited subjects with those of the population of Turin.

Figure 2 shows the spread of subjects by age group in both single and dual monitor studies together with the actual distribution for Turin. There was a bias towards the younger age groups, particularly for the dual monitor study, from the targeted 33% in each group. This is not surprising when you consider that over 60% of the actual population were aged below 35 y which gave rise to difficulties when recruiting workers in the 50-64 y age group.

The selected subjects closely matched the overall population of Turin based upon Mosaic group distribution, with the exception of groups A and E (Fig. 3). Group A consisted of larger households with professional/well-educated families, whereas Group E consisted of smaller households with younger families of lower education level with many unemployed or manual labourers. This difference between the geodemographic

distribution of recruited subjects and the overall city population may be attributable to the specific recruitment of "office" workers for the investigation of employed subjects in Turin.

The participants were restricted to a choice of 12 occupations from which to select and provide their answers on the first visit questionnaire. Table 4 lists these occupations and the answers that were provided by 105 subjects wearing the workplace monitor in this study.

#### WEATHER AND POLLUTANTS INFORMATION

Detailed information about the weather conditions during the course of the study were obtained from the local meteorological office in Turin and the levels of certain airborne pollutants obtained from the local Public Health office. The study was carried out during

Table 4. Occupations of the employed subjects (Turin).

Occupation	Number of responses
Administration	11
Building trade	2
Education	4
Engineering	3
Government	13
Legal	8
Leisure	2
Medical	16
Other	28
Retail	5
Science	9
Supply	4
Total	105

February/March 1995 with daily mean temperatures over this period varying from a minimum of 4.2°C to a maximum of 9.8°C. A maximum daily rainfall of 13.4 mm was recorded with rain falling on 5 d of the study period. Mean daily wind speeds varied between 0.4 and 3.9 m s<sup>-1</sup> and maximum and minimum relative humidities of 99% and 29%, respectively, were recorded. Concentrations of particles, NO, NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub>, and CO were also obtained from three monitoring stations situated around the Turin area. Daily mean NO<sub>2</sub> concentrations varied from 69 to 134 µg m<sup>-3</sup> and were in excess of 100 µg m<sup>-3</sup> on at least 5 d of the study period, when the air quality could be described as being poor. Particulate concentrations, expressed as daily means, varied from 57 to 202 µg m<sup>-3</sup> with an overall average of 119 µg m<sup>-3</sup> during the study period.

#### SMOKING STATUS

Saliva cotinine levels were determined in order to verify that recruited subjects had correctly reported themselves as nonsmokers. Various threshold levels, above which subjects would be classified as smokers, have been suggested and include 10 ng mL<sup>-1</sup> (Etzel 1990), 15 ng mL<sup>-1</sup> (McNeill et al. 1987), 30 ng mL<sup>-1</sup> (Lee 1987), and, more recently, 100 ng mL<sup>-1</sup> (Sterling et al. 1996). In this study, 25 ng mL<sup>-1</sup> (maximum of pre- and post- levels) was used, as chosen and described previously by these authors (Phillips et al. 1994), as a suitable cut off level. Using this threshold, three subjects, with levels between 31 and 50 ng mL<sup>-1</sup>, were assumed to be occasional smokers and excluded from the study.

Ten subjects were excluded from the study after admitting to being smokers on the first visit questionnaire, including users of pipes and/or cigars. Five of these subjects had saliva cotinine levels in excess of 100 ng mL<sup>-1</sup>, indicative of regular smokers. The remaining five subjects, whose levels varied between 0.5 and 14 ng mL<sup>-1</sup>, may have abstained from smoking for several days before the study started and/or were occasional smokers. Alternatively, they may have misreported their smoking status.

In this study, subjects were required to confirm they had been nonsmokers for more than 6 months and no attempt was made to differentiate between "non" and "never" smokers. Various criteria can be used to assess the rate at which recruited subjects misreport their smoking status, including responses to questionnaires. Depending upon the criteria used, the rate at which subjects misclassified their smoking status in this study ranged between 1.6% (3 from 191) and 6.5% (13 from 201). This compares with between 2.7% and 5.3% for Stockholm and between 10.5% and 17.8% for Barcelona, the values having been estimated in an identical way.

Etzel's (1990) review of the use of saliva cotinine for this purpose suggests that subjects with cotinine levels between 10 and 100 ng mL<sup>-1</sup> may be classified as infrequent smokers. Had 10 ng mL<sup>-1</sup> been selected as the cut-off level, a further 4 subjects would have been rejected. Delfino et al. (1993) rejected only 3 out of 251 subjects using a cut-off of 20 ng mL<sup>-1</sup>, whereas Sterling et al. (1996) could have rejected 2 out of 25 had they used a similar threshold level instead of 100 ng mL<sup>-1</sup>. In a study of cardiovascular risk factors in 5115 young adults (CARDIA), Wagenknecht et al. (1992) found a misclassification rate of 4.2% based on a serum cotinine cut-off of 14 ng mL<sup>-1</sup>. It is interesting to note that they classified nonsmokers as subjects having reported smoking less than 5 cigarettes per week for the previous 3 months. An exclusion rate of 4.2%, using a 15 ng mL<sup>-1</sup> saliva discrimination level, was also found on a recent personal air monitoring study (Jenkins et al. 1996) of 1564 subjects in the United States.

#### RESULTS AND DISCUSSION

The correlation and best fit line coefficients between various analytes used to assess ETS levels in this study are listed in Table 5. Table 6 depicts the same information following removal of data pairs where either analyte is below the LOQ. Cumulative frequency distributions for all analytes are presented in Figs. 4 and 5.

Table 5. Correlation coefficients for ETS 'markers' (Turin).

"Y" data	vs "X" data	Data pairs	R-squared	Gradient	Intercept
FPM	UVP	291	0.971	1.11	-0.80
SolPM	UVP	291	0.864	1.48	-10.27
SolPM	FPM	291	0.823	1.29	-8.27
3-EP	Nicotine	292	0.874	0.38	-0.07
FPM	Nicotine	290	0.633	11.05	6.89
SolPM	Nicotine	290	0.645	15.79	-1.07
UVP	Nicotine	290	0.637	9.87	7.06
SolPM	3-EP	290	0.668	39.83	-3.22
FPM	3-EP	290	0.668	28.11	5.27
Post-cotinine	Nicotine*	185	0.564	1.16	0.34
Post-cotinine	SolPM*	184	0.509	0.05	0.70
Post-cotinine	FPM*	184	0.445	0.07	0.20

\* Time-weighted average concentrations used for working subjects (Cells 3 to 6).

Table 6. Correlation coefficients for ETS 'markers' using data greater than the LOQ (Turin).

"Y" data	vs "X" data	Data pairs	R-squared	Gradient	Intercept
FPM	UVP	286	0.971	1.11	-0.83
SolPM	UVP	214	0.870	1.51	-11.81
SolPM	FPM	215	0.816	1.30	-9.07
3-EP	Nicotine	145	0.843	0.36	0.19
FPM	Nicotine	250	0.622	11.01	7.06
SolPM	Nicotine	198	0.615	15.59	0.15
UVP	Nicotine	245	0.630	9.81	7.51
SolPM	3-EP	137	0.594	40.62	-4.24
FPM	3-EP	143	0.659	28.03	5.73
Post-cotinine	Nicotine*	69	0.527	1.15	0.34
Post-cotinine	SolPM*	55	0.583	0.05	1.20
Post-cotinine	FPM*	77	0.507	0.08	0.62

\* Time-weighted average concentrations used for working subjects (Cells 3 to 6) having results from both the "workplace" and "outside of the workplace" monitors greater than the LOQ.

An excellent correlation ( $R^2=0.971$ ) between ETS particle measurements made using UVP and FPM methods was evident (Tables 5 and 6), with a gradient and intercept indicating close similarity between the results. This was also reflected in Fig. 4, where near identical ETS particle distributions using both UVP and FPM estimates were observed. The correlations of SolPM measurements compared with either UVP ( $R^2=0.864$ ) or FPM ( $R^2=0.823$ ) estimates were still

good, although gradient and intercept values indicated that ETS particle concentrations determined using SolPM measurements would give higher values than for UVP or FPM estimates above a certain concentration. This crossover point is clearly depicted in Fig. 4 and is equivalent to an ETS particle concentration of approximately  $25 \mu\text{g m}^{-3}$ . In three instances, SolPM estimates were higher than corresponding gravimetric determinations for RSP which did not occur with any

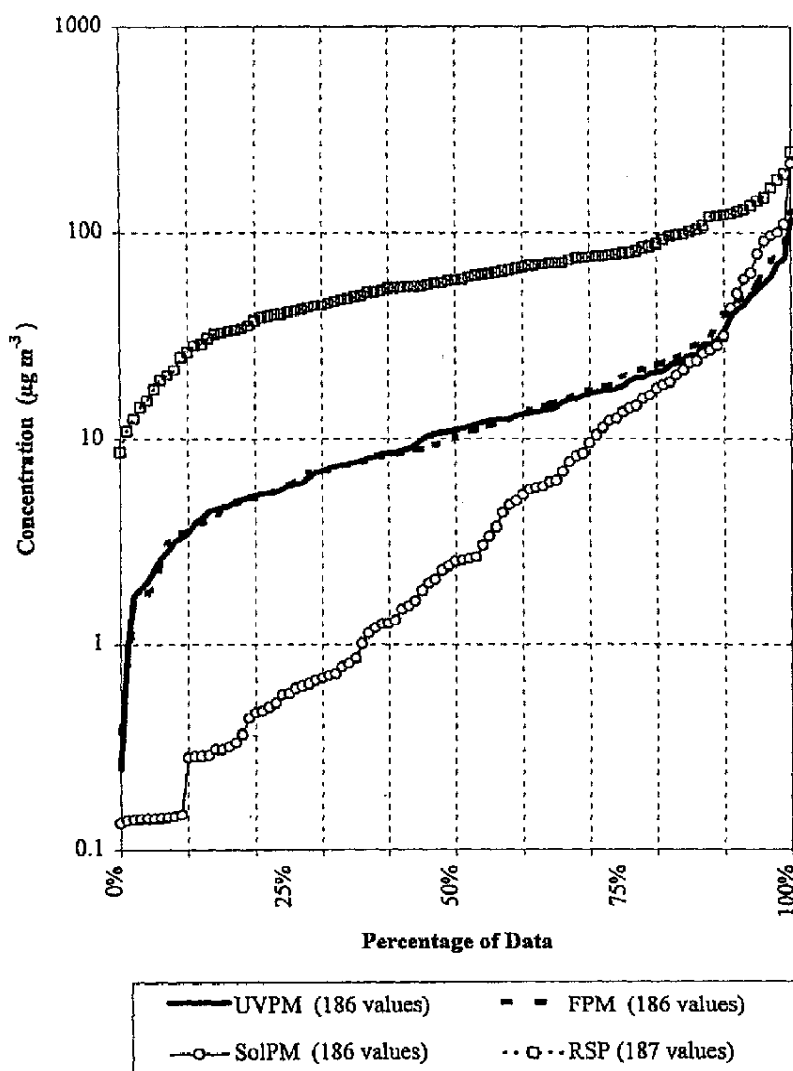


Fig. 4. Cumulative frequency distributions of mean 24-h particulate phase component concentrations and mean 24-h respirable suspended particle concentrations (Turin).

UVPM or FPM determinations. This phenomenon has been observed and discussed previously by these authors (Phillips et al. 1997) and was tentatively attributed to the factors used for calculating particulate concentrations.

It was also noted that 26% of SolPM results were below the LOQ compared with 0% and 1.7% for FPM and UVPM, respectively. Baek et al. (1997), studying air quality in Korean homes, offices, and restaurants, similarly reported a number of SolPM estimates higher than the corresponding FPM/UVPM results, together

with a high percentage of SolPM estimates below the LOQ. In this study, of the samples where SolPM estimates were below the LOQ, 68% had measurable nicotine concentrations in the range 0.11–1.2  $\mu\text{g m}^{-3}$  (median 0.29  $\mu\text{g m}^{-3}$ ) and 8% had quantifiable 3-EP levels (0.16–0.41  $\mu\text{g m}^{-3}$ , median 0.25  $\mu\text{g m}^{-3}$ ). It is possible that this apparent lack of sensitivity for SolPM determinations is due to the specificity of solanesol as a marker for ETS particles since the presence of nicotine may be attributed to other sources than directly from ETS (Nelson et al. 1990). Contrary to this,

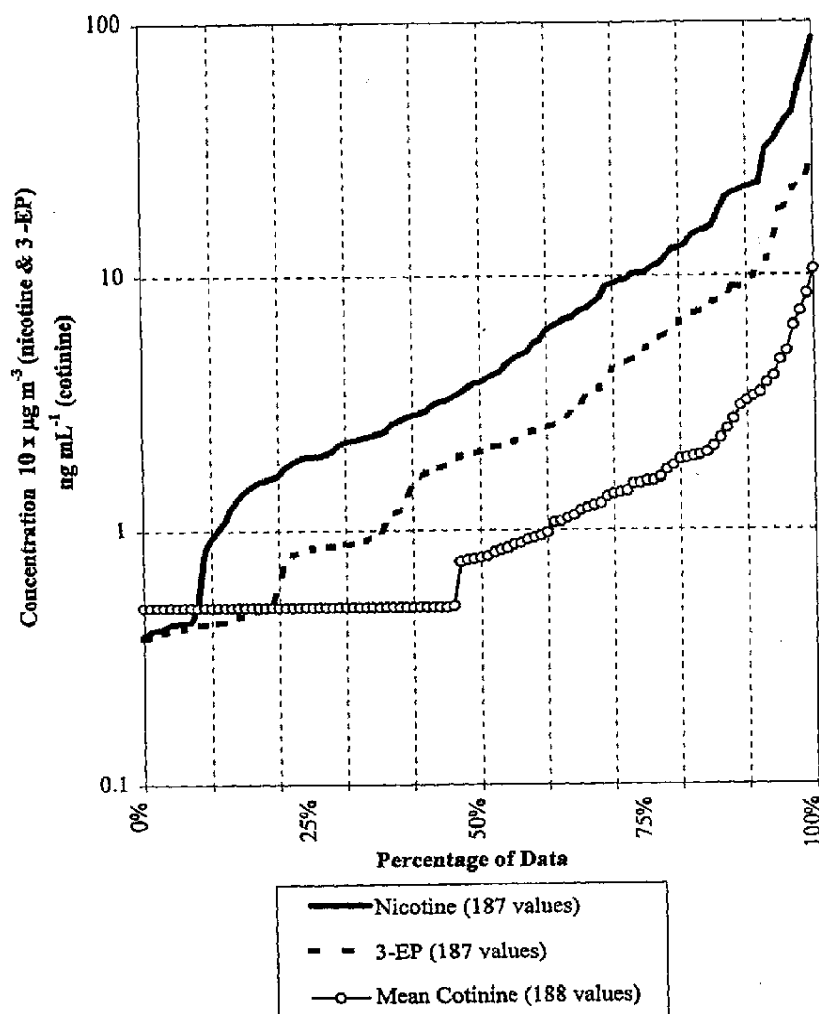


Fig. 5. Cumulative frequency distributions of mean 24-h vapour phase component concentrations and mean saliva cotinine concentrations (Turin).

Eatough (1993) concluded that "the concentration of gas phase nicotine underestimates exposure to the particulate phase of environmental tobacco smoke constituents".

In light of these and previous findings (Phillips et al. 1997), it was considered appropriate to report FPM particulate estimates alongside those for SolPM. Throughout this paper, ETS particle concentrations, corresponding exposure calculations, and comparisons between subject groups and Cells have been based

primarily upon SolPM estimates. These are currently considered to give the closest representation of actual ETS particle concentrations, but it should be noted that the results indicate that SolPM can overestimate ETS particle concentrations at high concentrations and may underestimate at low concentrations.

Determined nicotine and 3-EP concentrations showed good correlation with an  $R^2$  value of 0.874 and an intercept close to zero, suggesting no bias in either measurement. Correlation of these vapour phase ana-

Table 7. Summary statistics for 24-h mean particulate phase analytical data for all subjects by their household/workplace smoking status (Turin).

Analyte	Cell <sup>a</sup>	Number of subjects	10th percentile	90th percentile	Arithmetic mean	Geometric mean	Median
RSP ( $\mu\text{g m}^{-3}$ )	1 (SH)	36	23	140	83	66	71
	2 (NSH)	47	15	81	55	46	54
	3 (SH, SW)	21	39	127	80	70	80
	4 (SH, NSW)	9	44	132	84	74	66
	5 (NSH, SW)	50	32	99	63	56	59
	6 (NSH, NSW)	24	32	86	59	53	55
SolPM ( $\mu\text{g m}^{-3}$ )	1 (SH)	36	0.85	60	25	7.3	6.7
	2 (NSH)	47	0.14	2.9	3.8	0.51	0.47
	3 (SH, SW)	21	5.0	99	35	18	18
	4 (SH, NSW)	8	2.3	88	38	18	21
	5 (NSH, SW)	50	0.49	20	6.9	3.1	2.9
	6 (NSH, NSW)	24	0.29	8.1	3.5	1.3	1.3
FPM ( $\mu\text{g m}^{-3}$ )	1 (SH)	36	3.5	60	27	16	20
	2 (NSH)	47	1.7	13	8.5	5.8	6.8
	3 (SH, SW)	21	11	71	30	23	19
	4 (SH, NSW)	8	6.7	52	27	18	20
	5 (NSH, SW)	50	4.8	28	14	11	10
	6 (NSH, NSW)	24	3.9	15	9.6	8.2	8.3
UVP ( $\mu\text{g m}^{-3}$ )	1 (SH)	36	3.3	52	24	15	18
	2 (NSH)	47	1.9	12	8.8	6.1	7.0
	3 (SH, SW)	21	12	62	28	21	18
	4 (SH, NSW)	8	7.8	53	26	18	18
	5 (NSH, SW)	50	5.3	26	13	11	11
	6 (NSH, NSW)	24	3.9	16	9.9	8.4	8.3

<sup>a</sup>SH: smoking household; NSH: nonsmoking household; SW: smoking workplace  
NSW: nonsmoking workplace.

Time-weighted average exposure concentrations, determined for each subject from measured levels, both inside and outside the workplace, were used to calculate the above statistical parameters for Cells 3 to 6.

better correlations were apparent for 3-EP. The gradient of the regression line for 3-EP versus nicotine (Table 5) indicates nicotine levels more than twice those for corresponding 3-EP concentrations, resulting in 50% of determined 3-EP concentrations falling below the LOQ compared with only 14% for nicotine. Other authors have noted similar median nicotine:3-EP ratios of approximately 2:1 using active monitors (Sterling et al. 1996); passive monitors (Ogden 1996) have been found to give higher ratios of between 4:1 and 8:1. Although both nicotine and 3-EP concentra-

tions have been reported, subsequent exposure calculations have used nicotine values due to the lack of mainstream data for 3-EP and for ease of comparison with previous studies.

Table 5 shows the correlations for post-cotinine concentrations with both vapour and particle phase ETS components to be fairly weak, the best correlation apparent when post-cotinine levels were compared with nicotine ( $R^2=0.564$ ). However, Fig. 5 shows that, where cotinine levels were measureable, the distribution of concentrations was comparable to those for both

Table 8. Summary statistics for 24-h mean vapour phase analytical data and saliva cotinine levels for all subjects by their household/workplace smoking status (Turin).

Analyte	Cell #	Number of subjects	10th percentile	90th percentile	Arithmetic mean	Geometric mean	Median
Nicotine ( $\mu\text{g m}^{-3}$ )	1 (SH)	36	0.28	4.9	1.9	1.1	1.1
	2 (NSH)	47	0.04	0.60	0.32	0.14	0.14
	3 (SH, SW)	21	0.47	3.6	1.6	1.2	1.3
	4 (SH, NSW)	8	0.22	4.7	1.9	1.1	1.0
	5 (NSH, SW)	51	0.19	1.3	0.61	0.43	0.38
	6 (NSH, NSW)	24	0.16	0.87	0.41	0.31	0.25
3-EP ( $\mu\text{g m}^{-3}$ )	1 (SH)	36	0.10	2.2	0.74	0.43	0.52
	2 (NSH)	47	0.04	0.27	0.13	0.07	0.05
	3 (SH, SW)	21	0.20	1.8	0.83	0.63	0.79
	4 (SH, NSW)	8	0.13	2.0	0.94	0.58	0.61
	5 (NSH, SW)	51	0.09	0.62	0.29	0.22	0.21
	6 (NSH, NSW)	24	0.08	0.34	0.19	0.14	0.10
Cotinine* ( $\text{ng mL}^{-1}$ )	1 (SH)	36	0.50	6.4	2.4	1.5	1.4
	2 (NSH)	47	0.50	1.6	0.83	0.68	0.50
	3 (SH, SW)	21	0.50	5.2	2.4	1.6	1.7
	4 (SH, NSW)	9	0.50	3.9	2.1	1.5	1.5
	5 (NSH, SW)	51	0.50	1.9	0.98	0.81	0.77
	6 (NSH, NSW)	24	0.50	1.8	0.87	0.73	0.50

\* Values calculated from the average of pre- and post-monitoring saliva cotinine concentrations.

\* SH: smoking household; NSH: nonsmoking household; SW: smoking workplace;

NSW: Nonsmoking workplace.

Time-weighted average exposure concentrations, determined for each subject from measured levels, both inside and outside the workplace, were used to calculate the above vapour phase statistical parameters for Cells 3 to 6.

nicotine and 3-EP. These findings strengthen the theory that cotinine measurements are not currently a reliable marker for ETS exposure, and also suggest that the reliability may be improved with a lower LOQ. In this study, over 59% of post-cotinine determinations were below the LOQ.

#### *Concentrations of ETS constituents to which Turin subjects were exposed*

In this paper, median values have been used for reporting RSP and ETS exposures since data generated from this type of study are not normally distributed. Arithmetic and geometric means for each data set have also been reported together with 10th and 90th percentile values, also referred to as the lower and upper deciles, respectively, as a more appropriate indication of the range of values than the minimum and maxi-

mum. In the context of this paper, the term "exposure" can be taken to mean the "potential inhaled quantity", calculated as the product of the encountered concentration, the length of time subjected to such concentration, and the breathing rate maintained throughout the defined period. Where exposures have been quoted in terms of cigarette equivalents (CE), these have been calculated in relation to the mainstream particle and nicotine yields of typical Italian cigarettes. The values, 11 mg particles and 0.8 mg nicotine, were calculated from the mean yields of the top six selling cigarette brand-types in Italy.

Tables 7 and 8 show summary analytical data for all subjects by Cell with the corresponding cumulative frequency distributions for SolPM and nicotine depicted in Figs. 6 and 7.

The highest median RSP concentration found in this study ( $80 \mu\text{g m}^{-3}$ ) was for workers living in smoking

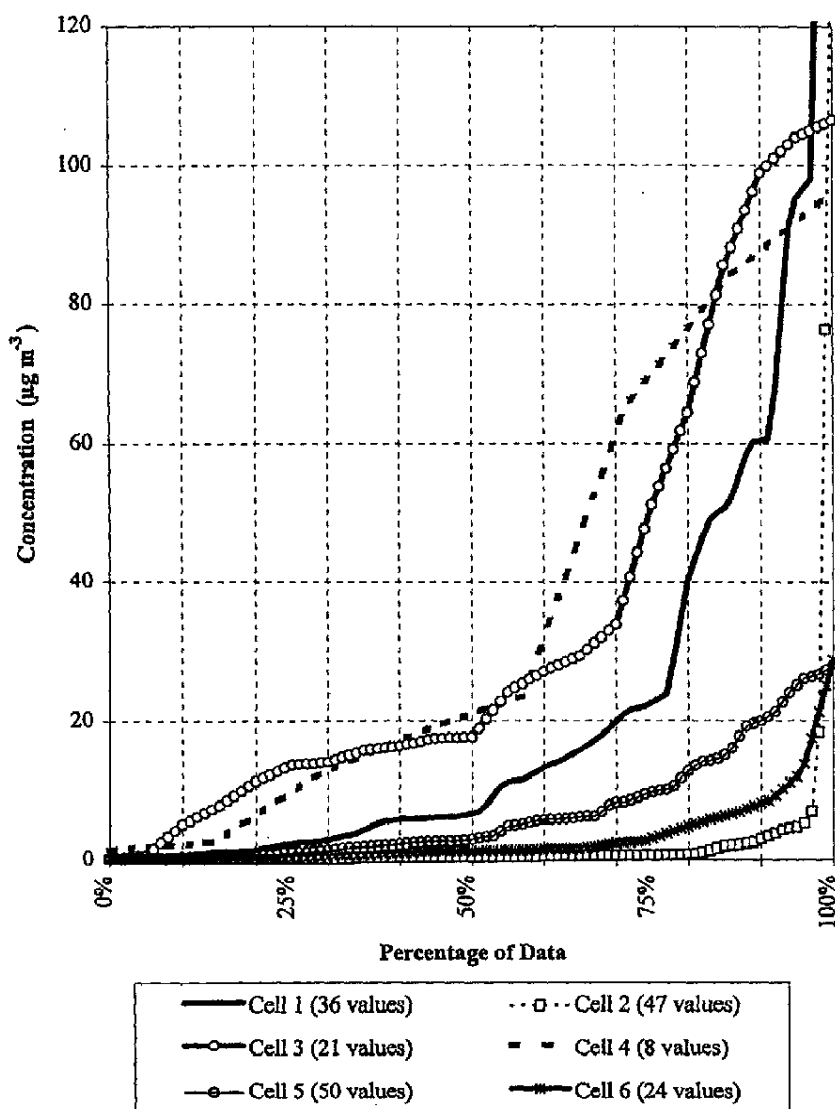


Fig. 6. Cumulative frequency distributions of SolPM by Cell (Turin).

households and working in smoking workplaces (Cell 3) with an ETS particle contribution of  $18 \mu\text{g m}^{-3}$  (22.5%) based upon SolPM measurements. These findings, however, were not significantly different ( $p > 0.05$ ) than for workers living in smoking households and working in nonsmoking workplaces (Cell 4) with median levels of  $66 \mu\text{g m}^{-3}$  and  $21 \mu\text{g m}^{-3}$  apparent for RSP and SolPM, respectively. Comparing these exposure concentrations with those for housewives living in smoking households (Cell 1), there was no significant difference ( $p > 0.05$ ) between RSP levels but a significantly lower median level of ETS particles

( $p \leq 0.001$ ) was apparent for these housewives ( $6.7 \mu\text{g m}^{-3}$  for SolPM). However, this lower median level of ETS particles was not apparent when a comparison of FPM or UVPm particle measurements was made. There was no significant difference ( $p > 0.05$ ) between median nicotine concentrations and saliva cotinine levels determined for subjects in Cells 1, 3, and 4.

Subjects belonging to Cells comprising nonsmoking households (2, 5, and 6) had significantly lower median ETS particle concentrations ( $p \leq 0.05$  based on SolPM) than for Cells comprising smoking households (1, 3,

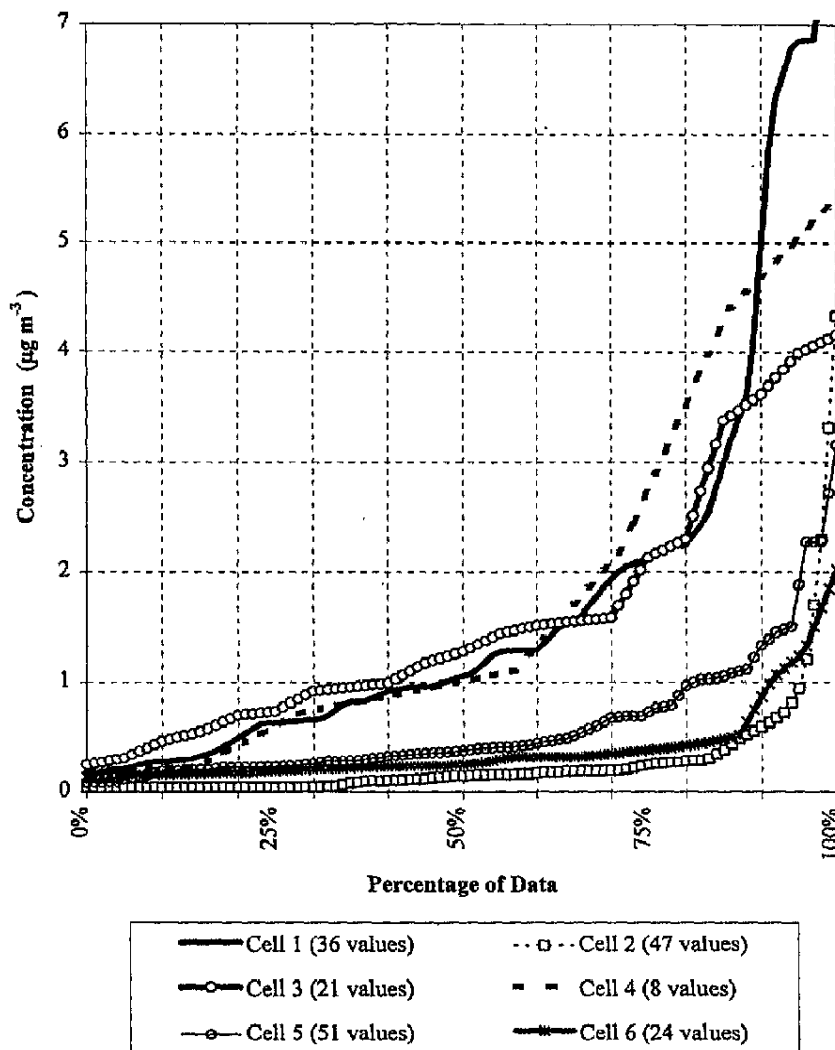


Fig. 7. Cumulative frequency distributions of nicotine by Cell (Turin).

and 4). A similar picture was evident for median nicotine concentrations, although for this analyte, there was no significant difference ( $p > 0.05$ ) between median levels determined for Cells 4 and 5. The lowest median exposures found in this study were for housewives living in nonsmoking homes who were exposed to  $54 \mu\text{g m}^{-3}$  RSP,  $0.47 \mu\text{g m}^{-3}$  ETS particles, and  $0.14 \mu\text{g m}^{-3}$  nicotine. ETS particle and nicotine levels were significantly lower ( $p \leq 0.01$ ) for housewives living in nonsmoking households (Cell 2) than for workers living in nonsmoking households irrespective of the smoking status of their workplace (Cells 5 and 6), however, there was no significant difference ( $p > 0.05$ )

between median RSP concentrations for Cells 2, 5, and 6. Median RSP and nicotine concentrations for subjects in Cells 5 and 6 were not significantly different ( $p > 0.05$ ) although ETS particle concentrations were higher for those subjects working in a smoking workplace (Cell 5,  $p \leq 0.05$ ).

The results indicate that the smoking status of the home has a greater influence on overall exposure to ETS particles and nicotine than the workplace, there being no significant difference found between median levels for housewives and workers residing in smoking households (ETS particles estimated using FPM). This is also supported by the fact that median levels for ETS

particles, nicotine, and saliva cotinine were significantly lower, except when comparing Cell 5 with Cell 4, for housewives and workers living in nonsmoking households. Cumulative frequency distributions for SolPM and nicotine (Figs. 6 and 7) clearly show the difference between exposure concentrations for subjects living in smoking households and those who do not. These differences in exposure were also mirrored by median saliva cotinine levels, values falling between 1.4 and 1.7 ng mL<sup>-1</sup> for those subjects living in smoking households and levels not exceeding 0.77 ng mL<sup>-1</sup> for those living in nonsmoking households.

The Wilcoxon rank sum test was used to determine the significance of any differences between concentrations by Cell. Prior to the application of this nonparametric test, Kruskal-Wallis nonparametric analysis of variance (ANOVA) was applied to the data to detect if there was a difference between at least two of the Cells. If the overall Kruskal-Wallis analysis proved nonsignificant, any significances detected using the Wilcoxon rank sum test would be considered spurious and likely to be a false positive. For all the analytes investigated, Kruskal-Wallis ANOVA provided confirmation of significance and subsequent pair-wise comparisons of Cells were performed using the Wilcoxon rank sum test (Table 9).

#### *Exposures to RSP, ETS particles, and nicotine*

Daily exposures, in terms of potential inhaled amounts (mg), calculated for each Cell over the 24-h monitoring period, are summarised in Table 10. A breathing rate of 0.65 m<sup>3</sup> h<sup>-1</sup>, the average level of respiration calculated for "awake" females, was used for calculating housewife exposures in Cells 1 and 2. For Cells 3 to 6, where exposures included both sexes, a breathing rate of 0.85 m<sup>3</sup> h<sup>-1</sup> was used, this being an average of the breathing rates for "awake" males (1.05 m<sup>3</sup> h<sup>-1</sup>) and females (0.65 m<sup>3</sup> h<sup>-1</sup>) as reported by Holcomb (1993). A comparable average breathing rate of 0.93 m<sup>3</sup> h<sup>-1</sup> was recently used by Jenkins et al. (1996) to estimate exposures on a large American study using similar personal monitoring methods to those in this study. Jenkins et al. (1996) calculated a daily nicotine intake of 0.014 mg for subjects either living and/or working in a smoking environment (a combination of their Cells 1, 2, and 3, equivalent to this study's Cells 3, 4, and 5). Daily exposures calculated for each Cell from the U.S. study's data are included in Table 10. Comparing these uncombined Cells, median exposures to nicotine were similar for subjects both

living and working in smoking environments but from 2 to 5 times less in the other Cells for the U.S. study compared to those reported for Turin. Corresponding exposures to RSP and ETS particles (SolPM) were between 2 and 30 times lower in all cases in the U.S. study. In this study, median daily exposures to ETS particles for working subjects living with smokers were more than 5 times higher than for those living with nonsmokers.

Daily exposures for housewives (Cells 1 and 2) may be multiplied by 365 to provide an estimate of annual exposure. This calculation assumes that the measured daily exposure is maintained throughout the year and that there is no alteration to exposure concentrations during weekends/holidays when more time may be spent outside the home or in the presence of the spouse. Accordingly, housewives living in smoking households would be exposed annually to approximately 404 mg RSP, 38 mg ETS particles, and 6.3 mg nicotine, significantly higher than for housewives living in nonsmoking households who would be exposed to approximately 307 mg RSP, 2.7 mg ETS particles, and 0.8 mg nicotine per y. These annual exposures to ETS particles in Turin are approximately half those observed for housewives in Barcelona (Phillips et al. 1997), although corresponding nicotine exposures were higher in Turin (0.8 vs 0.6 mg for nonsmoking households; 6.3 vs 4.2 mg for smoking households). Annual exposures, based upon upper decile concentrations for those living in smoking households, representative of the most highly exposed housewives in this study, were 797 mg RSP, 342 mg ETS particles, and 28 mg nicotine.

Based on median levels and a typical Italian cigarette delivering 11 mg particles and 0.8 mg nicotine to the smoker, housewives living in nonsmoking households would be exposed to approximately 1 CE/y or less, compared with between 3.5 and 7.9 CE/y for housewives living in smoking households.

The magnitude of exposures to RSP, ETS particles, and nicotine for working subjects, both inside and outside of the workplace, were assessed using data provided by the individual monitors. Individual monitor contributions were combined to provide an estimate of exposure concentrations in smoking and nonsmoking environments, both inside and outside the workplace, as presented in Tables 11 and 12. Comparison of saliva cotinine levels was not meaningful in this case and the data has been excluded from the tables.

As would be expected, median levels of RSP, ETS particles, and nicotine were found to be higher in

Table 9. Significance of differences in ETS marker concentrations between cells based upon Kruskal-Wallis ANOVA and subsequent Wilcoxon rank sum test (Turin).

SolPM		Cell 3	Cell 1	Cell 4	Cell 5	Cell 6	Cell 2
	Median	18	6.7	21	2.9	1.3	0.47
vs Cell 3	18	--					
vs Cell 1	6.7	*	--				
vs Cell 4	21	NS	NS	--			
vs Cell 5	2.9	***	*	**	--		
vs Cell 6	1.3	***	***	**	*	--	
vs Cell 2	0.47	***	***	***	***	**	--
FPM		Cell 3	Cell 1	Cell 4	Cell 5	Cell 6	Cell 2
	Median	19	20	20	10	8.3	6.8
vs Cell 3	19	--					
vs Cell 1	20	NS	--				
vs Cell 4	20	NS	NS	--			
vs Cell 5	10	***	*	NS	--		
vs Cell 6	8.3	***	**	*	NS	--	
vs Cell 2	6.8	***	***	**	***	NS	--
Nicotine		Cell 3	Cell 1	Cell 4	Cell 5	Cell 6	Cell 2
	Median	1.3	1.1	1.0	0.38	0.25	0.14
vs Cell 3	1.3	--					
vs Cell 1	1.1	NS	--				
vs Cell 4	1.0	NS	NS	--			
vs Cell 5	0.38	***	***	NS	--		
vs Cell 6	0.25	***	***	*	NS	--	
vs Cell 2	0.14	***	***	***	***	***	--
Cotinine		Cell 3	Cell 1	Cell 4	Cell 5	Cell 6	Cell 2
	Median	1.7	1.4	1.5	0.77	0.50	0.50
vs Cell 3	1.7	--					
vs Cell 1	1.4	NS	--				
vs Cell 4	1.5	NS	NS	--			
vs Cell 5	0.77	**	**	NS	--		
vs Cell 6	0.50	**	**	*	NS	--	
vs Cell 2	0.50	***	***	**	NS	NS	--

NS: not significant ( $p > 0.05$ ); \*:  $p \leq 0.05$ ; \*\*:  $p \leq 0.01$ ; \*\*\*:  $p \leq 0.001$ .

Cell 1: Smoking household;

Cell 2: Nonsmoking household;

Cell 3: Smoking household/smoking workplace;

Cell 4: Smoking household/nonsmoking workplace;

Cell 5: Nonsmoking household /smoking workplace;

Cell 6: Nonsmoking household/nonsmoking workplace.

Table 10. Calculated 24-h exposures to RSP, ETS particles, and nicotine assuming median and 90th percentile air concentrations (Turin).

Cell <sup>a</sup>	RSP (mg)		SolPm (mg)		Nicotine (mg)	
	Median	90th percentile	Median	90th percentile	Median	90th percentile
1 (SH)	1.11	2.18	0.10	0.94	0.017	0.076
2 (NSH)	0.84	1.26	0.01	0.05	0.002	0.009
3 (SH, SW)	1.63	2.59	0.37	2.02	0.027	0.073
Jenkins et al.*	0.75		0.084		0.033	
4 (SH, NSW)	1.35	2.69	0.43	1.80	0.020	0.096
Jenkins et al.*	0.52		0.021		0.011	
5 (NSH, SW)	1.20	2.02	0.06	0.41	0.008	0.027
Jenkins et al.*	0.46		0.002		0.002	
6 (NSH, NSW)	1.12	1.75	0.03	0.17	0.005	0.018
Jenkins et al.*	0.34		0.002		0.001	

<sup>a</sup> SH: smoking household; NSH: nonsmoking household; SW: smoking workplace;

NSW: nonsmoking workplace.

NB: A breathing rate of 0.65 m<sup>3</sup> h<sup>-1</sup> was assumed for housewives (Cells 1-2) and 0.85 m<sup>3</sup> h<sup>-1</sup> for working subjects (Cells 3-6).

\* Data calculated from comparable cells in Jenkins et al. (1996) and using their breathing rate of 0.93 m<sup>3</sup> h<sup>-1</sup>.

Table 11. Summary analytical statistics for employed subjects outside the workplace based on their household smoking status (Turin).

Analyte	Cell*	Number of subjects	10th percentile	90th percentile	Arithmetic mean	Geometric mean	Median
RSP (µg m <sup>-3</sup> )	3 & 4	30	35	135	76	64	63
	5 & 6	75	22	90	52	45	46
SolPM (µg m <sup>-3</sup> )	3 & 4	30	0.82	97	33	12	16
	5 & 6	75	0.21	7.8	2.6	0.88	0.74
FPM (µg m <sup>-3</sup> )	3 & 4	30	6.1	67	26	17	17
	5 & 6	75	2.3	15	9.9	6.9	7.5
UVPM (µg m <sup>-3</sup> )	3 & 4	30	5.4	55	24	16	18
	5 & 6	75	2.3	16	9.1	6.8	7.8
Nicotine (µg m <sup>-3</sup> )	3 & 4	29	0.20	2.8	1.6	0.95	0.97
	5 & 6	75	0.07	0.40	0.27	0.20	0.19
3-EP (µg m <sup>-3</sup> )	3 & 4	29	0.07	2.0	0.90	0.52	0.75
	5 & 6	75	0.06	0.25	0.13	0.10	0.07

\* Cells 3 & 4: smoking household; Cells 5 & 6: nonsmoking household.

smoking environments than in nonsmoking environments. Working subjects living in smoking households were exposed to the highest median concentration of ETS particles based upon SolPM of 16 µg m<sup>-3</sup>. This median concentration falls to 9.1 µg m<sup>-3</sup> in the smoking workplace. However, when the same comparisons were made using FPM estimates, there was no apparent difference between median concentrations either inside (16 µg m<sup>-3</sup>) or outside the workplace (17 µg m<sup>-3</sup>). There was also no apparent difference

between median nicotine concentrations found outside the workplace for those living in smoking homes (0.97 µg m<sup>-3</sup>) and the smoking workplace (0.99 µg m<sup>-3</sup>). Median levels determined for ETS particle and vapour phase components in nonsmoking environments were also similar, although there was an indication that levels of nicotine in the workplace were higher than those outside the workplace.

Estimations of annual exposures for workers, performed using an assumed 35-h working week and

Table 12. Summary analytical statistics for employed subjects at work based on their workplace smoking status (Turin).

Analyte	Cell*	Number of subjects	10th percentile	90th percentile	Arithmetic mean	Geometric mean	Median
RSP ( $\mu\text{g m}^{-3}$ )	3 & 5	71	20	172	92	72	90
	4 & 6	33	28	100	73	60	64
SolPM ( $\mu\text{g m}^{-3}$ )	3 & 5	71	0.44	80	30	7.8	9.1
	4 & 6	32	0.41	7.4	2.6	1.3	0.92
FPM ( $\mu\text{g m}^{-3}$ )	3 & 5	71	3.1	80	31	17	16
	4 & 6	32	3.4	13	8.4	6.7	7.5
UVP ( $\mu\text{g m}^{-3}$ )	3 & 5	71	3.4	75	29	17	18
	4 & 6	32	3.5	15	9.0	7.4	8.3
Nicotine ( $\mu\text{g m}^{-3}$ )	3 & 5	72	0.24	5.4	1.9	1.0	0.99
	4 & 6	33	0.23	0.92	0.52	0.42	0.41
3-EP ( $\mu\text{g m}^{-3}$ )	3 & 5	72	0.13	2.1	0.83	0.51	0.51
	4 & 6	33	0.11	0.44	0.24	0.19	0.16

\* Cells 3 & 5: smoking workplace; Cells 4 & 6: nonsmoking workplace.

Table 13. Annual exposures to RSP, ETS particles, and nicotine for employed subjects (Turin).

Environment	Annual exposure (mg)			Cigarette equivalents	
	RSP	ETS particles*	Nicotine	SolPM	Nicotine
Median levels					
Smoking home	379	96	5.8	8.7	7.3
Nonsmoking home	277	4.5	1.1	0.4	1.4
Smoking work	129	13	1.4	1.2	1.8
Nonsmoking work	91	1.3	0.6	0.1	0.7
Upper decile levels					
Smoking home	812	584	17	53	21
Nonsmoking home	542	47	2.4	4.3	3.0
Smoking work	246	114	7.7	10	9.6
Nonsmoking work	143	11	1.3	1.0	1.6

\* Estimated using solanesol measurements (SolPM).

NB. A 35-h working week and 48-week working year were assumed in the calculation of annual exposure at work. The remainder of the time outside of the workplace was assumed to be at 'home'. An average breathing rate of  $0.85 \text{ m}^3 \text{ h}^{-1}$  was assumed at all times and the median/upper decile concentrations in the various locations were taken from the 'combined Cell' data reported in Tables 11 and 12. Overall annual exposure can be estimated by summing the data from the requisite 'home' and 'work' locations.

48-week working year are reported in Table 13. Median and upper decile exposures for RSP in Turin were comparable with those previously reported for Barcelona (Phillips et al. 1997) as were exposures to ETS particles and nicotine for workers outside the workplace living in smoking households. Subjects working in smoking workplaces in Turin would be exposed annually to approximately 13 mg ETS particles (determined using SolPM) and 1.4 mg nicotine, considerably less than

annual exposures determined for the smoking workplace in Barcelona (53 mg and 3.4 mg, respectively). Combining the calculated figures from Table 13, the estimated annualised exposure based on median levels for subjects both living in smoking households and working in smoking workplaces would be between 8.5 and 10.5 CE/y compared to between 1.1 and 1.5 CE/y for subjects living and working in nonsmoking environments.

Table 14. Median concentrations of RSP and ETS related analytes for housewives living in Stockholm, Barcelona, and Turin.

Analyte	Home status	City		
		Stockholm	Barcelona	Turin
RSP ( $\mu\text{g m}^{-3}$ )	smoking	39	63	71
	nonsmoking	18	51	54
ETS particles (SolPM) ( $\mu\text{g m}^{-3}$ )	smoking	17	11	6.7
	nonsmoking	0.12	1.0	0.47
ETS particles (FPM) ( $\mu\text{g m}^{-3}$ )	smoking	5.0	13	20
	nonsmoking	0.31	4.4	6.8
Nicotine ( $\mu\text{g m}^{-3}$ )	smoking	1.1	0.74	1.1
	nonsmoking	0.05	0.11	0.14
Pre-cotinine ( $\text{ng mL}^{-1}$ )	smoking	2.9	1.4	1.4
	nonsmoking	0.56	0.50	0.50
Post-cotinine ( $\text{ng mL}^{-1}$ )	smoking	2.9	1.1	1.5
	nonsmoking	0.41	0.50	0.50

Table 15. Median concentrations of RSP and ETS related analytes for employed subjects living in Stockholm, Barcelona, and Turin.

Analyte		Smoking status*	City		
			Stockholm	Barcelona	Turin
			At work		
RSP	( $\mu\text{g m}^{-3}$ )	smoking	16	94	90
		nonsmoking	16	52	64
ETS particles (SolPM)	( $\mu\text{g m}^{-3}$ )	smoking	1.1	37	9.1
		nonsmoking	0.42	2.6	0.92
ETS particles (FPM)	( $\mu\text{g m}^{-3}$ )	smoking	1.4	30	16
		nonsmoking	0.58	10	7.5
Nicotine	( $\mu\text{g m}^{-3}$ )	smoking	0.20	2.4	0.99
		nonsmoking	0.15	0.71	0.41
Outside the workplace					
RSP	( $\mu\text{g m}^{-3}$ )	smoking	24	85	63
		nonsmoking	19	40	46
ETS particles (SolPM)	( $\mu\text{g m}^{-3}$ )	smoking	1.4	21	16
		nonsmoking	0.20	2.2	0.74
ETS particles (FPM)	( $\mu\text{g m}^{-3}$ )	smoking	2.0	25	17
		nonsmoking	0.47	4.2	7.5
Nicotine	( $\mu\text{g m}^{-3}$ )	smoking	0.15	0.86	0.97
		nonsmoking	0.07	0.17	0.19

\* Smoking status outside the workplace refers to household smoking status.

Tables 14 and 15 provide a comparison of median levels, determined for both working subjects and housewives, from the three European cities investigated to date by these authors.

#### SUBJECTIVE COMPARISONS OF ETS EXPOSURE

The ETS exposures of individuals in smoking and nonsmoking environments have been extensively investigated as part of this study. The smoking "status" of a workplace was defined by the absence/presence of smoking co-workers within 30 m of the volunteer's workstation and no consideration was taken regarding the employer's rules or local authority regulations. This definition was chosen for consistency across different countries as Health and Safety regulations and employers/employees attitudes towards smoking vary considerably. It is interesting to note that information from subjects' diaries, completed during the monitoring periods and last visit survey questionnaires, indicated that approximately 21% of subjects working in smoking environments did not see or smell any smoking during the monitoring period. Also significant was the fact that about 42% of all subjects working in nonsmoking environments noted smoking during the monitoring period.

From analysis of diaries and combining the single and dual monitor studies, 9.1% of subjects living in a smoking household did not note smoking taking place during the monitoring period. Conversely, 31% of subjects living in a nonsmoking household did note smoking taking place. Subjects who reported smoking taking place during the monitoring period were exposed to higher median concentrations of RSP and all the ETS markers than those subjects who did not report smoking activities.

As part of the last visit survey, study subjects were asked a number of subjective questions regarding their exposure to ETS, both in general and during the 24-h monitoring period. Table 16 lists the various environments and the percentage of subjects believing that it is the single environment in which they are most exposed to tobacco smoke. Approximately 4 out of 5 people believed they were most exposed to ETS outside the workplace. Also evident is the general perception of the highest exposure location being restaurants/bars. This study was unable to distinguish between the various locations outside of the workplace, hence, more work on this topic may be required to confirm the subjective findings.

Table 16. Subjective assessment of the environment where subjects consider themselves to be most exposed to ETS (Turin).

Environment	% of responses *
Restaurant/bar	31.9
Work	18.6
Home	17.0
In other buildings	11.2
Outdoors	3.7
Nowhere/not exposed	3.2
Travelling/driving	2.1

\* Responses calculated as a percentage of total recruits, 23 subjects failed to answer this question correctly.

#### CONCLUSIONS

Turin was the third in a series of European cities investigated by these authors assessing exposures to RSP and ETS in a randomly selected sample of the nonsmoking population. The most highly exposed subjects in this study were employed subjects living in households where smoking takes place, irrespective of the smoking status of the workplace. Daily exposures to ETS particles and nicotine based upon median levels were at least 5 times higher than for those subjects residing in nonsmoking households, indicating the significance of ETS exposure contributions resulting from living in a smoking household. The highest levels of RSP were apparent for those subjects both living and working in smoking environments. The least exposed subjects in this study were housewives living in nonsmoking households, who were exposed to significantly lower levels than those for working subjects living in nonsmoking households, irrespective of the smoking status of their workplace. There were also no significant differences between the median levels of ETS particles (FPM) and nicotine determined for housewives and workers living in smoking households, which suggests that the smoking status of the home has the greatest influence on overall exposures to ETS particles and nicotine.

Comparison of the findings for Turin with those reported for Stockholm (Phillips et al. 1996) and Barcelona (Phillips et al. 1997) showed that the median levels reported for employed subjects were similar to those reported for Barcelona, although there was an indication that concentrations of ETS particles and nicotine were higher in the workplaces of Barcelona inhabitants. The levels were significantly higher than

those determined for employed subjects in Stockholm, which were considered to be among the lowest recorded for any sizeable urban area. For housewives, the median level of exposure to ETS particles (SolPM) for subjects living in smoking households in Stockholm was higher than for Barcelona or Turin, corresponding nicotine levels being comparable.

Making comparisons between exposures determined for these European cities is fairly straightforward since the data were generated and published in a similar format. Making direct comparisons with other studies investigating exposure is more difficult since there are many different ways of presenting the data. Jenkins et al. (1996), in their recent U.S. study, investigated personal exposures to ETS for working subjects in 16 cities using a similar protocol to that used for employed subjects in the European studies, which has enabled an almost direct comparison of findings. Median levels determined for RSP, ETS particles, and nicotine in the U.S. were typically less than 50% of the levels determined in Turin with the exception of nicotine levels for subjects both living and working in smoking environments, which were comparable.

Using a threshold level of 25 ng mL<sup>-1</sup> for saliva cotinine to determine whether occasional smokers had reported themselves as nonsmokers, between 1.6 and 6.5% of subjects were considered to have misreported their smoking status. This compares with an exclusion rate of 4.2% found on the recent personal monitoring study for 1564 subjects in the U.S. which used a discrimination level of 15 ng mL<sup>-1</sup> for saliva cotinine (Jenkins et al. 1996). Although saliva cotinine measurements were not intended for use as a marker for ETS exposure, median levels determined for subjects living and working exclusively in nonsmoking environments were below the LOQ. Corresponding median levels for those subjects living and/or working in smoking environments were above the LOQ with the highest median levels apparent for subjects both living and working in smoking environments (1.7 ng mL<sup>-1</sup>). These findings indicate there is a potential use for saliva cotinine measurements in the assessment of ETS exposure, providing a method with a greatly improved LOQ can be used.

Problems associated with the determination of ETS particle concentrations using solanesol as a marker have been reported previously by these authors (Phillips et al. 1997) and were again evident during the course of the study in Turin. Where elevated levels of ETS particles were measured, a number of SolPM

estimates were higher than those made using UVPM and FPM methodologies. Quantifiable levels of nicotine and 3-EP were also found in some instances where levels of ETS particles (SolPM) were below the LOQ. From inspection of the data published by Baek et al. (1997), studying indoor air quality in Korea, a number of SolPM estimates exceeding those for UVPM and FPM were also apparent. Sterling et al. (1996) also documented problems associated with the same methods for the estimation of ETS particle concentrations and reported a high degree of variability and a number of anomalous results. A collaborative investigation of these analytical methods in the future may define the underlying reasons for this phenomenon.

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